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(54) **HEAT-SANITIZATION OF SURFACES**

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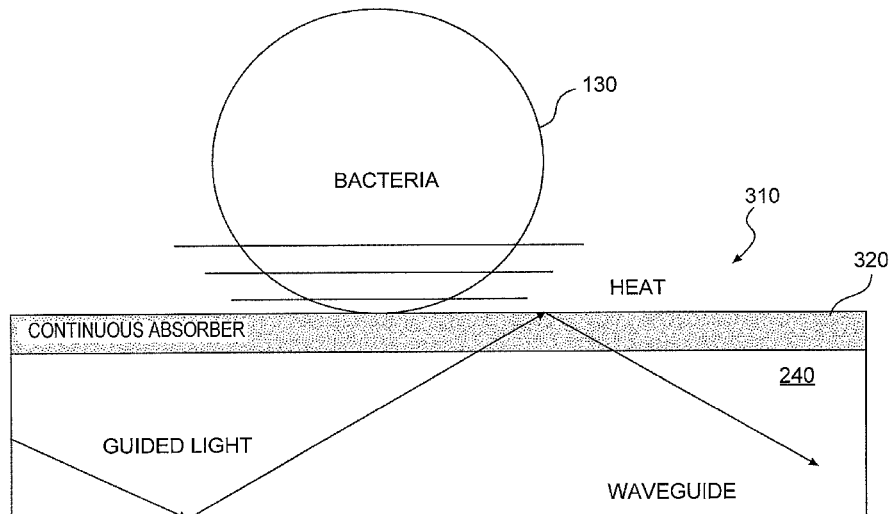
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(57) **ABSTRACT**

Solutions for limiting the undesirable spread of pathogens by indirect contact are provided. The solutions involve heat-sanitization of contact regions on articles or fixtures by flowing selected electromagnetic radiation energy through underlying waveguide structures substantially parallel to the contact regions.

**16 Claims, 6 Drawing Sheets**



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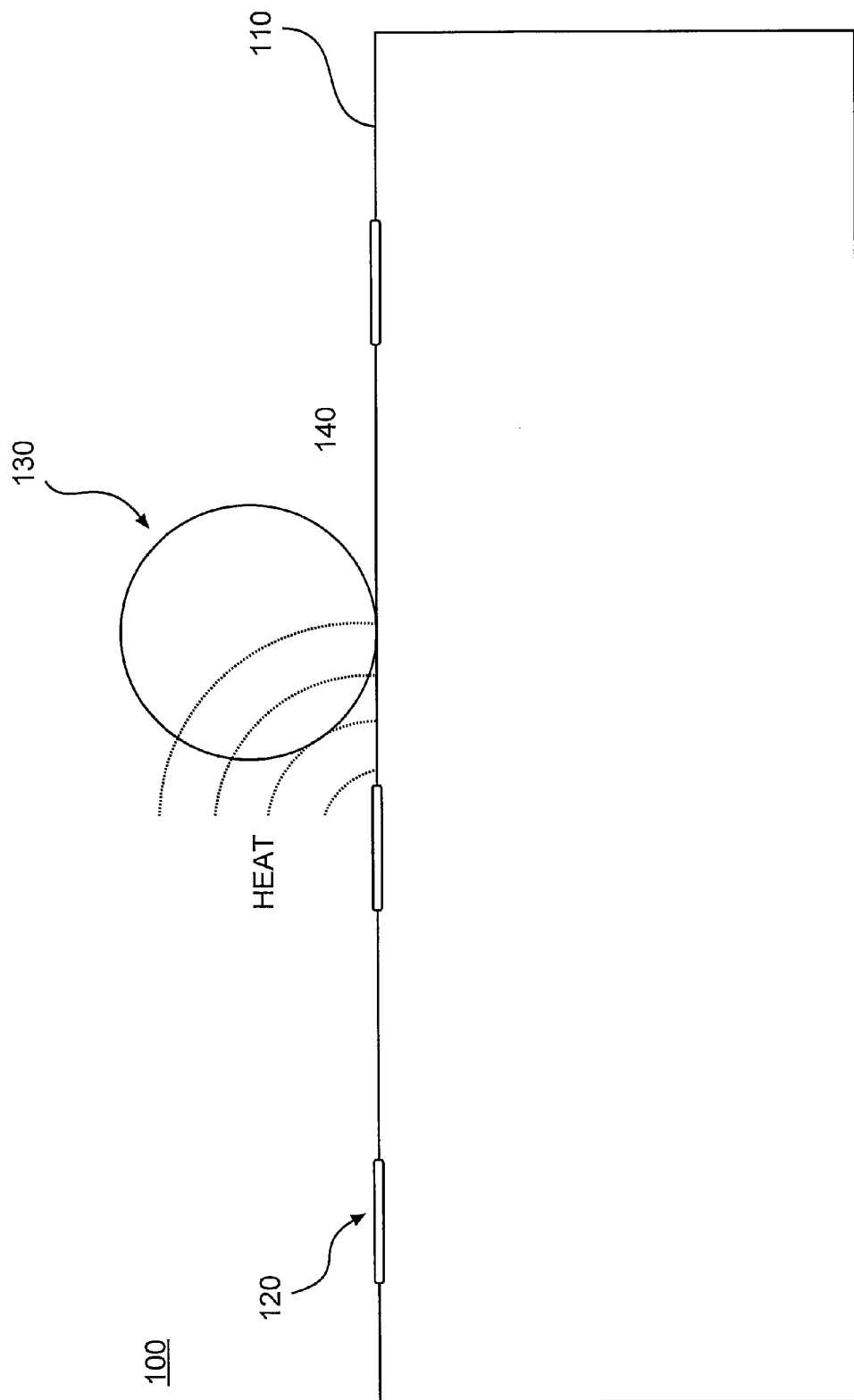
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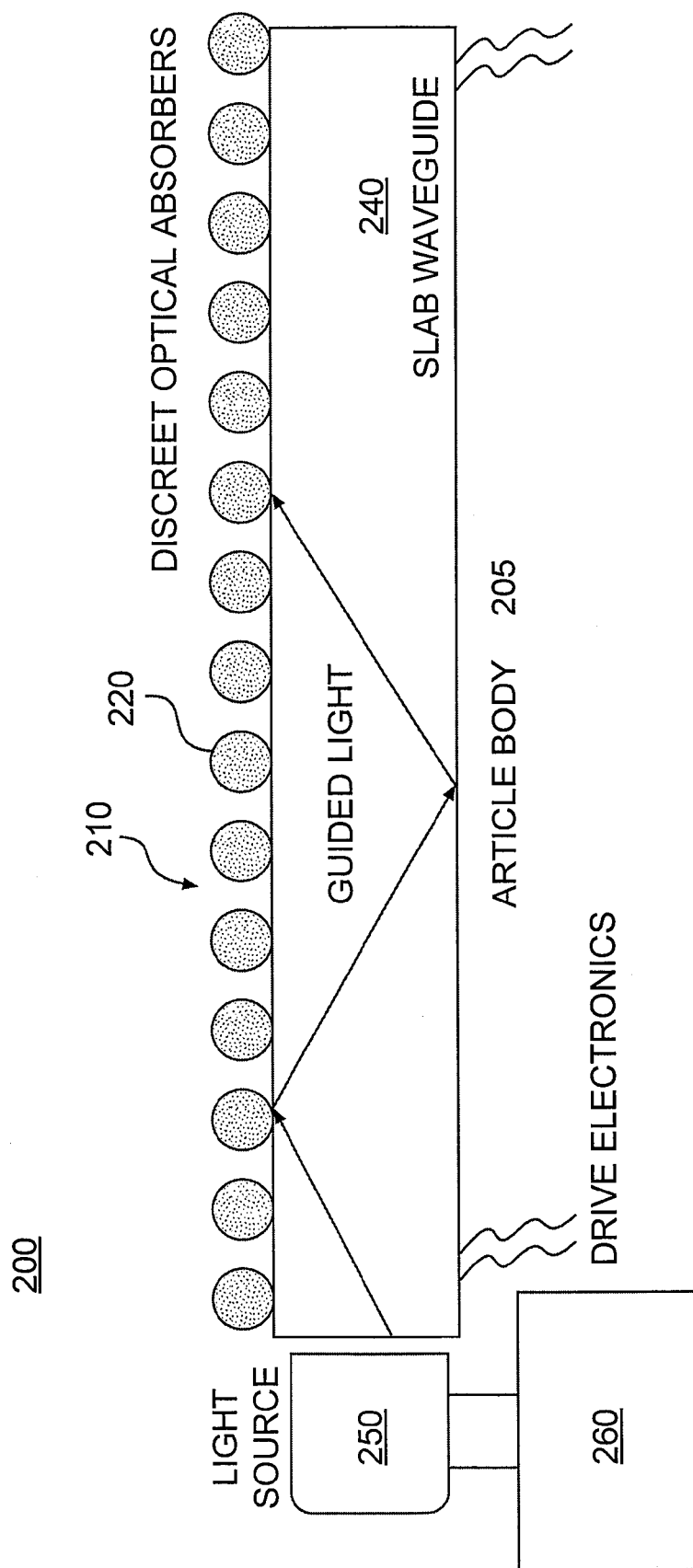
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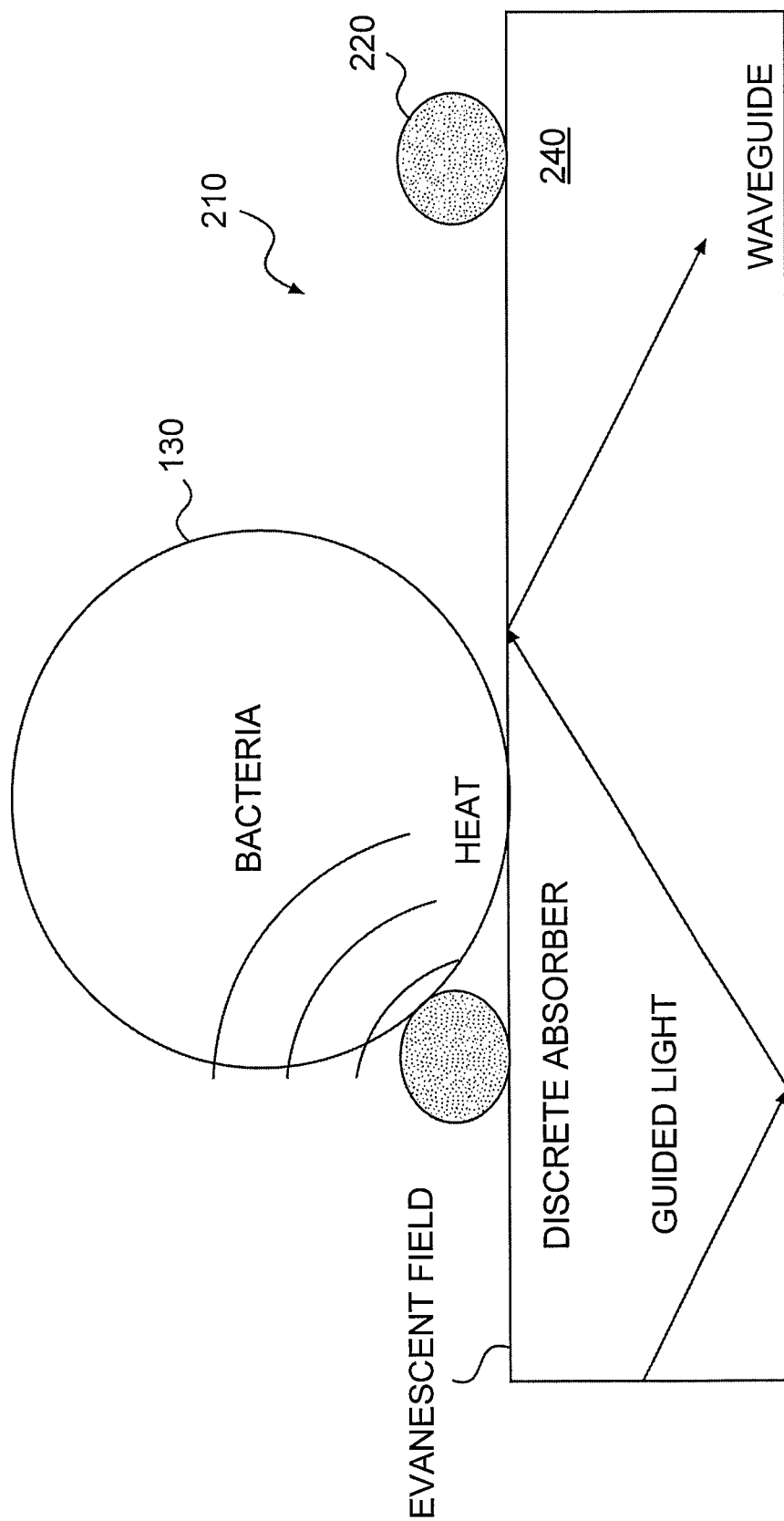
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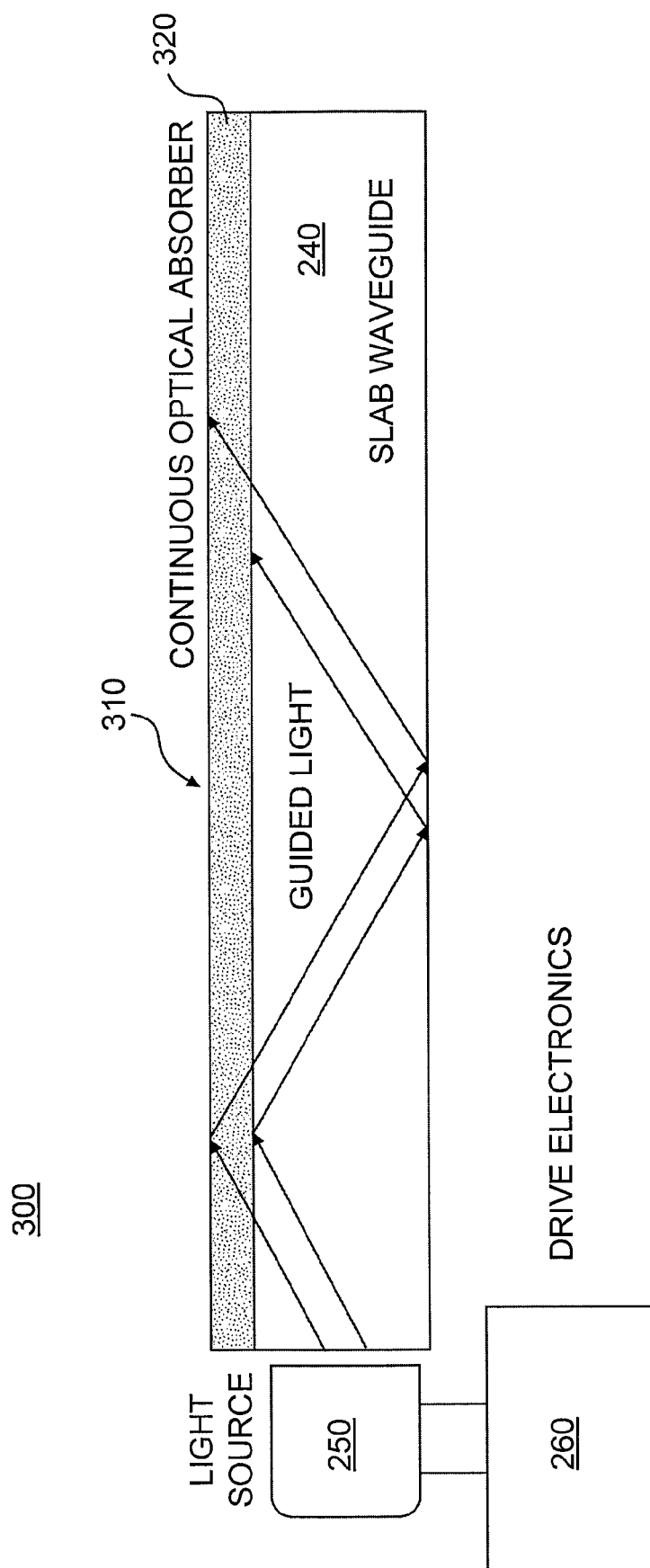
**FIG. 1**



**FIG. 2A**

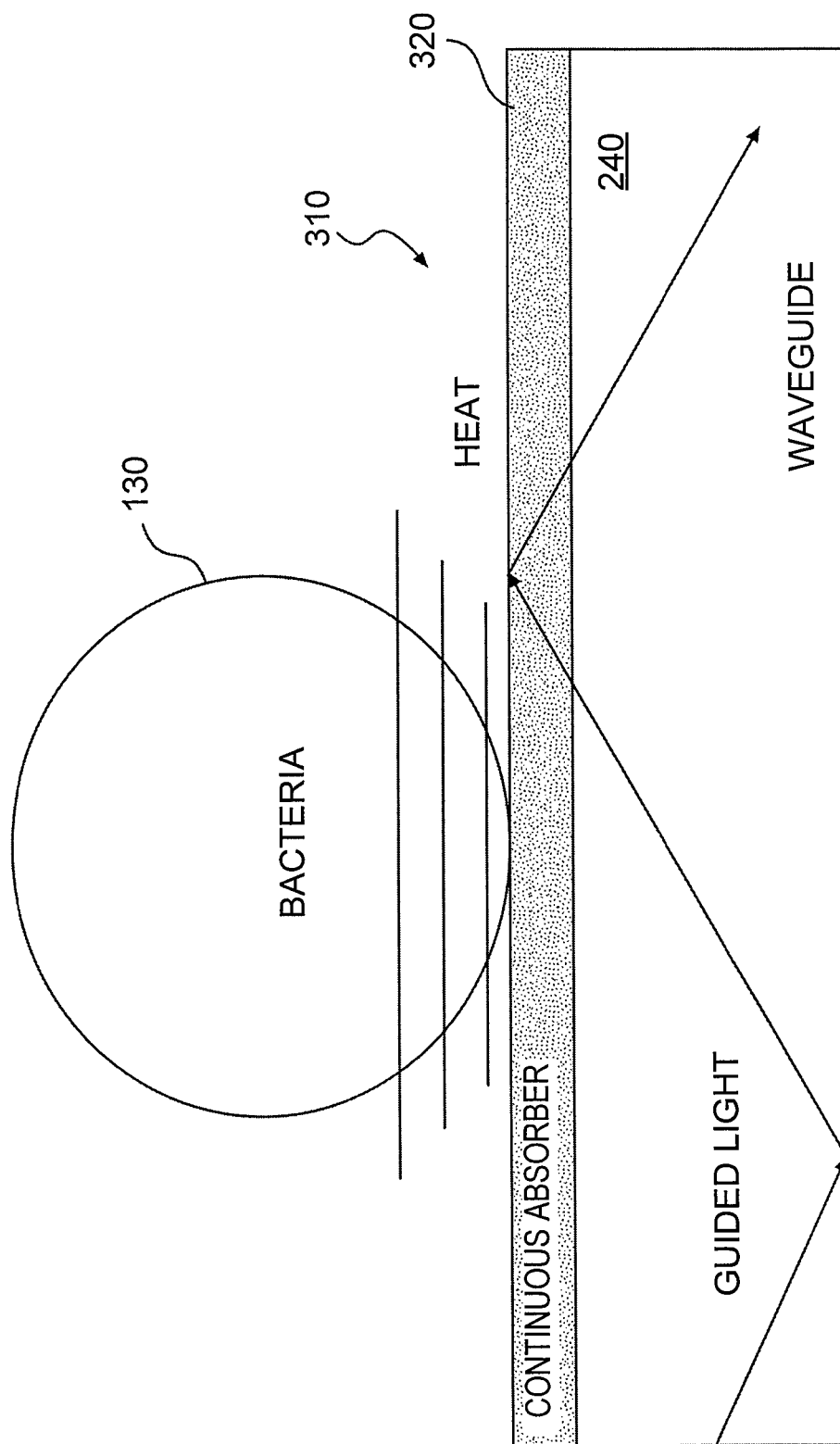


**FIG. 2B**



**FIG. 3A**





**FIG. 3B**

FIG. 4

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providing a selected electromagnetic radiation absorber portion in the outer surface region; and

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flowing selected electromagnetic radiation energy through an underlying waveguide structure substantially parallel to the outer surface region so that the selected electromagnetic radiation absorber portion is coupled to and heated by the electromagnetic radiation energy flow to a positive temperature that heat-sanitizes an exposed portion of the outer surface region.

## HEAT-SANITIZATION OF SURFACES

## BACKGROUND

Diseases and infections can be transmitted by indirect contact. Any contact surface, which is touched by more than one person, can be a transfer point for harmful germs spreading diseases and infections through a population. An example is the common cold. A person, who has a cold, can leave cold virus behind on a door handle he or she touches. A non-infected person, who later touches the door handle, can pick up the cold virus from the door handle and catch the same cold.

For certain high risk environments (e.g., restrooms, food service and health care facilities), public health programs recommend hand washing or hand rubbing routines for maintaining good hand hygiene to prevent or reduce propagation of communicable diseases and infections. However, time and facilities constraints present are major obstacles to maintaining good hand hygiene. Many studies of nosocomial infections show that hand washing protocols are not properly followed even by health care providers. General compliance rates of health care providers with hospital-recommended hand washing or hand rubbing protocols are low. The poor compliance rates have been attributed in part to a lack of knowledge of when and how to clean or disinfect hands, and in part to time constraints and poor access to hand washing facilities or hand rubbing products. (See e.g., Albert R. K., Condie F., NEJM 1981; 304(24):1465-6).

The time and facilities constraints that impede good hand hygiene in hospital environments are even more severe obstacles for achieving good hand hygiene in other public environments. For example, it is not practical to provide hand washing facilities at every touch screen in an airport, or at ATM or contact surface in a bank. Further, even where hand washing facilities are provided (e.g., in restrooms), hand washing can be counterproductive. A person, after washing hands, could pick up germs by turning a water faucet handle off, or touching a restroom exit door handle.

Consideration is now being given to other solutions for limiting the undesirable spread of pathogens by indirect contact. Some such solutions may avoid, for example, the time and facilities constraints that hinder solutions that rely on voluntary hand washing by individuals.

## SUMMARY

Approaches to limiting the spread of pathogens, for example, by indirect contact are provided.

The foregoing summary is illustrative only and is not intended to be limiting. In addition to the illustrative aspects, embodiments, and features described above, further aspects, embodiments, and features of the solutions will become apparent by reference to the drawings and the following detailed description.

## BRIEF DESCRIPTION OF THE FIGURES

In the accompanying drawings:

FIG. 1 is a schematic illustration of an exemplary article having a contact surface that can be heat-sanitized to kill, impair or remove microbial growth, in accordance with the principles of the solutions described herein.

FIGS. 2A and 2B are schematic illustrations of an exemplary article having a contact surface that can be heat-sanitized to kill, impair or remove microbial growth, in accordance with the principles of the solutions described herein.

FIGS. 3A and 3B are schematic illustrations of another exemplary article having a contact surface that can be heat-sanitized to kill, impair or remove microbial growth, in accordance with the principles of the solutions described herein.

FIG. 4 is a flow diagram of an exemplary method for heat-sanitizing article surfaces, in accordance with the principles of the solutions described herein.

Throughout the figures, unless otherwise stated, the same reference numerals and characters are used to denote like features, elements, components, or portions of the illustrated embodiments.

## DESCRIPTION

In the following description of exemplary embodiments, reference is made to the accompanying drawings, which form a part hereof. It will be understood that embodiments described herein are exemplary, but are not meant to be limiting. Further, it will be appreciated that the solutions described herein can be practiced or implemented by other than the described embodiments. Modified embodiments or alternate embodiments may be utilized, in the spirit and scope of the solutions described herein.

Sterilization, disinfection, and sanitization of an object are terms that may have specific meanings corresponding to various degrees of control of microbial growth. Sterilization of a surface may, for example, refer to killing of all microbial growth on the surface. Disinfection of a surface may refer to reducing the number of viable microorganisms on the surface, and sanitization may refer to cleaning the surface to reduce or remove a number of the microorganisms. However, for convenience in description, a single term "sanitization" may be used herein to describe any degree of control of microbial growth including, for example, any killing or reduction of viable microbial growth that may be otherwise described by the terms sterilization or disinfection.

Sanitization of a surface, in general, requires application of suitable chemical or physical antimicrobial agents to the surface to kill, impair or remove the microbes. Exemplary chemical antimicrobial agents include surfactants, various organic acids and bases, heavy metals, halogen-containing compounds, alcohols, phenol and phenolics, oxidizing agents, alkylating agents, dyes, etc. Exemplary physical antimicrobial agents include heat, ultraviolet radiation, ultrasonic waves, etc.

The sanitization agents are usually applied externally to the surfaces periodically or in between use of the surfaces. In many cases, the surfaces (e.g., touch screens, key boards, etc.) are in continuous use or must be continuously available for use. Sanitization of such surfaces by application of external physical or chemical agents may require interruption of the surfaces availability for use. In contrast, the sanitization techniques and solutions described herein may be used to sanitize surfaces without interrupting their use or availability.

In one approach, surface sanitization may be achieved by localized heating of surface portions to destroy or impair pathogens or other organic life forms. FIG. 1 shows, for example, an article 100 with an exterior surface 110 which includes a heat-radiating or re-radiating portion 120. Heat, which is radiated from portion 120, may be intense enough to kill or impair a microorganism 130 in local region 140. In accordance with the principles of the solutions described herein, energy for reradiation as heat is delivered to the heat-radiating portion 120 for heat-sanitization in a manner that does not significantly interfere with use or operation of surface 110 or article 100.

In one approach, energy is delivered to the heat-radiating portions of the surface in the form of electromagnetic energy. The electromagnetic energy may be delivered specifically to the heat-radiating portions via a suitable wave guide structure. The heat-radiating portions of the surfaces may, for example, directly or indirectly absorb energy propagating through the suitable wave guide structure and reradiate such absorbed energy as heat.

The heat-radiating portions of the surfaces (e.g., surface portions **120**) may also be referred to herein interchangeably as heat- or energy-absorbing portions as appropriate in the context of the description of the functions of such portions (i.e., absorbing energy or re-radiating such energy as heat).

FIGS. 2A and 2B show an exemplary self-sanitizing article **200** having an article body **205** and an exterior surface **210**, which includes a number of discrete heat-radiators (e.g., optical absorbers/re-radiators **220**). Article **200** may be a device or fixture of any shape having one or more surfaces such as surface **210** that can be touched or contacted in use. Article **200** may, for example, be a computer or electronic display terminal, an electronic touch screen, a computer mouse or control device, a handle, a hand rail, a seat, a key board, a switch, a button, a knob, a computer mouse or control device, a desktop, a bathroom or kitchen or other working surface, a bus seat, a gymnasium apparatus or fixture, a restaurant booth or seat, a toy, a headphone, a telephone, an automatic teller machine, a vending machine, a shopping cart, a household device or fixture, a building device or fixture, an industrial device or fixture, a transport vehicle device or fixture, a medical device or fixture, or any other device or fixture whose contact surfaces are sites for potential transfer of undesirable pathogens amongst users.

Article **200** is configured so that outer surface region **210** can be periodically or continuously heat-sanitized by heat radiated by electromagnetic radiation absorber portions (e.g., discrete optical absorbers/re-radiators **220**). Exterior contact surface **210**, which includes optical absorbers/re-radiators **220**, is disposed proximate to a electromagnetic radiation waveguide structure **240** (e.g., a slab waveguide), which is configured to guide selected electromagnetic radiation energy internally therethrough substantially parallel its outer surface region. Geometrically, the electromagnetic radiation waveguide structure **240** is interposed between article body **205** and exterior contact surface **210**. Waveguide structure **240**, may be made of any suitable material that is transparent to the selected electromagnetic radiation energy. Exemplary waveguide materials include glass, ceramic, plastics, polymers, quartz, CaF, Al<sub>2</sub>O<sub>3</sub>, Si<sub>3</sub>N<sub>4</sub>, and any combination thereof. Further in instances where the outer surface region **210** forms the exterior of an electronic display screen and/or an electronic touch screen or other visual device, waveguide structure **240** may be substantially transparent to a viewer of the underlying display.

Article **200** may include an internal source of electromagnetic radiation (e.g., light source **250**) or be coupled to an external source that provides electromagnetic radiation energy for flow through electromagnetic radiation waveguide structure **240**. The frequency of wavelength of the electromagnetic energy may be selected in conjunction with the design or structure of electromagnetic radiation waveguide structure **240** so that most if not all of the electromagnetic energy flow is in the lateral direction substantially parallel the waveguide's outer surface region. Source **250** may be configured to provide radiation of suitable wavelength and to inject such radiation into the waveguide structure. Source **250** may, for example, be an ultraviolet light source, an infrared light source, a short pulse laser, a LED and/or a flash bulb.

Suitable electronics (e.g., drive electronics **260**) may be deployed to control operation of the source of electromagnetic radiation. Source **250** may be configured so that selected electromagnetic radiation propagating or flowing through waveguide structure **240** is in the form of short duration electromagnetic pulses. The pulses may have any suitable pulse width, for example, in the range of about nanoseconds to milliseconds.

In operation, the electromagnetic radiation absorber portions (**220**) are coupled to and heated by the electromagnetic radiation energy flow through the waveguide structure **240** to a positive temperature to heat-sanitize an exposed portion of exterior contact surface **210**. Article **200** may be designed to have suitable positive temperature values for local heat sanitization. The suitable positive temperature values may, for example, be selected with consideration of the particular type of microorganisms that may expected on the surface and empirical knowledge of the critical temperatures required to kill or impair such microorganisms. The positive temperature values may be in the range of about 10° C. to 100° C. above ambient. In some versions of article **200**, the suitable positive temperature values may exceed 100° C.

The electromagnetic radiation absorber portions **220** along a length of the waveguide structure may be coupled to and heated by an evanescent field component of the selected electromagnetic radiation energy flow through the waveguide structure. (See e.g., FIG. 2B). Alternatively or additionally, the waveguide structure may be configured to have multiple internal reflections of the electromagnetic radiation energy flow therethrough. The electromagnetic radiation absorber portions **220** may be coupled to and heated directly by portions of the electromagnetic radiation energy flow that undergo total internal reflection in the waveguide's exterior surface region **210**. FIG. 3A shows an exemplary article **300** which has a structure similar to that of article **200**, but in which the electromagnetic radiation absorber portion **320** is a substantially continuous adlayer which directly absorbs energy from electromagnetic radiation that undergoes reflection in surface region **310** of waveguide structure **240**. The adsorbed energy is reradiated as heat to kill or impair microorganisms (e.g., bacteria **130**) in the vicinity (FIG. 3B).

Electromagnetic radiation absorber portions **220** that are shown, for example, in FIGS. 2A and 2B, may include radiation-absorbing particles. These particles may be metallic particles that include one or more of gold, silver, aluminum, platinum, carbon nanotubes, and vanadium dioxide particles.

The particles may be nanoparticles that have suitably small dimensions (e.g., 20-200 nm) so that they exhibit size-dependent non-linear behavior. See e.g. John Kiran Anthony et al. "Particle size-dependent giant nonlinear absorption in nanostructured Ni—Ti alloys," *Optics Express* (2008) Volume: 16, Issue: 15, Pages: 11193-11202; Venkatram N. et al. "Size dependent multiphoton absorption and refraction of CdSe nanoparticles," *Opt Express*. 2007 Sep. 17; 15(19):12258-63; and Soumen Dhara et al. "Size-dependent visible absorption and fast photoluminescence decay dynamics from freestanding strained silicon nanocrystals," *Nanoscale Res Lett*. 2011 Apr. 11; 6(1):320.

The radiation-absorbing particles included in electromagnetic radiation absorber portions **220** may be nanoparticles that have sufficiently small dimensions so that they exhibit resonant coupling to and enhanced absorption of portions of the electromagnetic radiation energy flow in waveguide structure **240**. The nanoparticles included in electromagnetic radiation absorber portions **220** may, for example, be gold nanoparticles having dimensions of about 20 nanometers which exhibit non-linear absorption of infrared radiation. An

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exemplary article **200** may have gold nanoparticles of about 20 nanometers as radiation absorbers **220** and an electromagnetic radiation energy flow through waveguide structure **240** of IR pulses having pulse widths of about 1 nanosec.

It will be understood that article **200** may include an arrangement of optical elements (not shown) that configured to direct the selected electromagnetic radiation energy generated by the radiation source into the waveguide structure.

Article **200** may further include a contact sensor configured to determine if a contact has been made to an exposed portion of the outer surface region and to accordingly activate radiation source **250** to provide the selected electromagnetic radiation energy to waveguide structure **240** for heat-sanitization of the exposed portion of the outer surface region **210**. The contact sensor is any one of a capacitive, a resistive, a mechanical, a piezoelectric, a thermal, an ultrasonic, or an optical sensor.

Some versions of article **200** may include a programmable mechanism or controller configured to control activation of radiation source **250** to provide the selected electromagnetic radiation energy to the waveguide structure for heat-sanitization of an exposed portion of the outer surface region. The programmable mechanism or controller may control activation of the radiation source to provide the selected electromagnetic radiation energy to the waveguide structure for heat-sanitization of an exposed portion of the outer surface region according to a predetermined schedule. Alternatively or additionally, the controller may be configured to heat-sanitize the exposed portion of the outer surface region a predetermined time interval after a contact has been made. Article **200** may optionally include a user-activated switch configured to control activation of the radiation source to provide the selected electromagnetic radiation energy to the waveguide structure for heat-sanitization of an exposed portion of the outer surface region according to a user command. Article **200** may further optionally include a status indicator configured to indicate a sanitization state of the outer surface region.

FIG. 4 shows exemplary features of a method **400** for inhibiting germ transmission from contact surfaces. The method involves heat-sanitizing of an outer surface region of an article by heat-radiators included in the contact surfaces. Method **400** includes providing a selected electromagnetic radiation absorber portion in the outer surface region (**410**) and flowing selected electromagnetic radiation energy through an underlying waveguide structure substantially parallel to the outer surface region so that the selected electromagnetic radiation absorber portion is coupled to and heated by the electromagnetic radiation energy flow to a positive temperature that heat-sanitizes an exposed portion of the outer surface region (**420**). The positive temperature achieved by method **400** may be in the range of about 10° C. to 100° C. and higher above ambient as may be appropriate to provide effective heat sanitization.

In method **400**, the selected electromagnetic radiation absorber portion may be a substantially continuous adlayer extending over a portion of the waveguide structure or may include discrete absorbers (e.g., radiation-absorbing particles) distributed over a portion of the waveguide structure. The radiation-absorbing particles may be nanoparticles having sufficiently small dimensions that allow resonant coupling to and enhanced absorption of portions of the electromagnetic radiation energy flow. In method **400**, the selected electromagnetic radiation absorber portion may be coupled to and heated by an evanescent field component of the selected electromagnetic radiation energy flow through the waveguide structure. The selected electromagnetic radiation absorber

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portion may be coupled to and heated directly by portions of the electromagnetic radiation energy flow that undergo total internal reflection.

Further, in method **400** the selected electromagnetic radiation may include short duration electromagnetic pulses, for example, having pulse widths in the range of about nanoseconds to milliseconds.

Method **400** includes configuring a radiation source to provide the selected electromagnetic radiation energy to the waveguide structure. The radiation source so provided may be an ultraviolet light source, an infrared light source, a short pulse laser, a LED, and/or a flash bulb. Method **400** may optionally include providing an arrangement of optical elements to direct the selected electromagnetic radiation energy generated by the radiation source into the waveguide structure.

Method **400** may further include providing a contact sensor configured to determine if a contact has been made to an exposed portion of the outer surface region and to accordingly activate the radiation source to provide the selected electromagnetic radiation energy to the waveguide structure for heat-sanitization of the exposed portion of the outer surface region.

Method **400** may also include providing a programmable mechanism or other controller configured to control activation of the radiation source to provide the selected electromagnetic radiation energy to the waveguide structure for heat-sanitization of an exposed portion of the outer surface region. Method **400** may accordingly include using such programmable mechanism or other controller to provide the selected electromagnetic radiation energy to the waveguide structure for heat-sanitization of an exposed portion of the outer surface region according to a predetermined schedule, a predetermined time interval after a contact has been made and/or according to a user command.

Method **400** may further include providing a status indicator configured to indicate a sanitization state of the outer surface region.

All of the above U.S. patents, U.S. patent application publications, U.S. patent applications, foreign patents, foreign patent applications and non-patent publications referred to in this specification and/or listed in any Application Data Sheet are incorporated herein by reference, to the extent not inconsistent herewith.

While various aspects and embodiments have been disclosed herein, other aspects and embodiments will be apparent to those skilled in the art. The various aspects and embodiments disclosed herein are for purposes of illustration and are not intended to be limiting, with the true scope and spirit being indicated by the following claims.

The invention claimed is:

1. A self-sanitizing article, comprising:
  - an electromagnetic radiation waveguide structure; and
  - an outer surface region disposed proximate to the electromagnetic radiation waveguide structure,
 wherein the outer surface region has a selected electromagnetic radiation absorber portion and forms the exterior of at least one of an electronic display screen or an electronic touch screen,
  - wherein the electromagnetic radiation waveguide structure is configured to flow selected electromagnetic radiation energy internally therethrough substantially parallel to the outer surface region, and
  - wherein the selected electromagnetic radiation absorber portion is disposed relative to the waveguide structure so that it is coupled to and heated by the electromagnetic

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radiation energy flow to a positive temperature to heat-sanitize an exposed portion of the outer surface region.

2. The article of claim 1, wherein the waveguide structure is substantially transparent to a viewer of the at least one of the electronic display screen or the electronic touch screen.

3. A self-sanitizing article, comprising:  
an electromagnetic radiation waveguide structure;  
an outer surface region disposed proximate to the electromagnetic radiation waveguide structure; and  
a status indicator configured to indicate a sanitization state of the outer surface region,

wherein the outer surface region has a selected electromagnetic radiation absorber portion,

wherein the electromagnetic radiation waveguide structure is configured to flow selected electromagnetic radiation energy internally therethrough substantially parallel to the outer surface region, and

wherein the selected electromagnetic radiation absorber portion is disposed relative to the waveguide structure so that it is coupled to and heated by the electromagnetic radiation energy flow to a positive temperature to heat-sanitize an exposed portion of the outer surface region.

4. A self-sanitizing article, comprising:  
an electromagnetic radiation waveguide structure;  
an outer surface region disposed proximate to the electromagnetic radiation waveguide structure,  
wherein the outer surface region has a selected electromagnetic radiation absorber portion,

wherein the electromagnetic radiation waveguide structure is configured to flow selected electromagnetic radiation energy internally therethrough substantially parallel to the outer surface region, and

wherein the selected electromagnetic radiation absorber portion is disposed relative to the waveguide structure so that it is coupled to and heated by the electromagnetic radiation energy flow to a positive temperature to heat-sanitize an exposed portion of the outer surface region;  
a radiation source configured to provide the selected electromagnetic radiation energy to the waveguide structure; and

a contact sensor configured to determine if a contact has been made to an exposed portion of the outer surface region and to accordingly activate the radiation source to provide the selected electromagnetic radiation energy to the waveguide structure for heat-sanitization of the exposed portion of the outer surface region.

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5. The article of claim 4, wherein the selected electromagnetic radiation provided by the radiation source comprises short duration electromagnetic pulses.

6. The article of claim 4, wherein the selected electromagnetic radiation absorber portion is a substantially continuous adlayer extending over a portion of the waveguide structure.

7. The article of claim 4, wherein the selected electromagnetic radiation absorber portion includes discrete absorbers distributed over a portion of the waveguide structure, the discrete absorbers being physically separate from one another.

8. The article of claim 7, wherein discrete absorbers include radiation-absorbing particles.

9. The article of claim 8, wherein the radiation-absorbing particles are nanoparticles having sufficiently small dimensions that allow resonant coupling to and enhanced absorption of portions of the electromagnetic radiation energy flow.

10. The article of claim 4, wherein the radiation source is an infrared light source.

11. The article of claim 4, further comprising, a programmable mechanism configured to control activation of the radiation source to provide the selected electromagnetic radiation energy to the waveguide structure for heat-sanitization of an exposed portion of the outer surface region.

12. The article of claim 4, further comprising, a controller configured to control activation of the radiation source to provide the selected electromagnetic radiation energy to the waveguide structure for heat-sanitization of an exposed portion of the outer surface region according to a predetermined schedule.

13. The article of claim 4, further comprising, a user-activated switch configured to control activation of the radiation source to provide the selected electromagnetic radiation energy to the waveguide structure for heat-sanitization of an exposed portion of the outer surface region according to a user command.

14. The article of claim 4, wherein the outer surface region forms the exterior of at least one of an electronic display screen or an electronic touch screen.

15. The article of claim 14, wherein the waveguide structure is substantially transparent to a viewer of the at least one of the electronic display screen or the electronic touch screen.

16. The article of claim 4, further comprising, a status indicator configured to indicate a sanitization state of the outer surface region.

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